

Federal Diesel Research Study

May 5, 2011
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California Environmental Protection Agency



Air Resources Board

Federal Diesel Fuel Testing Program Status

- Draft Final Report completed and circulated to the panel members
- Statistical analysis was conducted based on methods developed by CARB

Chassis Dynamometer Fuel Test Matrix For each Test Vehicle

Test Day	Morning Schedule (assumes 6 replicates)	Afternoon Schedule (assumes 6 replicates)
ARB HHDDT Cruise Test Cycle		
Day 1	CCC AAA	AAA CCC
Day 2	CCC BBB	BBB CCC
Day 3	AAA CCC	CCC BBB

C = CARB diesel, A = Federal A diesel, B = Federal B diesel

Engine Dynamometer Fuel Test Matrix For each Test Engine

Test Day				
Heavy-Duty FTP Test Cycle				
Day 1	CCC	AAA	AAA	BBB
Day 2	BBB	CCC		
ARB HHDDT Cruise Test Cycle				
Day 2			CCC	AAA
Day 3	AAA	BBB	BBB	CCC

C = CARB diesel fuel, A = Federal A diesel fuel, B = Federal B diesel fuel

Chassis Dyno Vehicle Targeted and Actual Test Matrix

	Target	Actual
1991-1993	1 vehicle	None
1994-1997	1 vehicle	1 vehicle
1998-2002	2 vehicles (1 retrofit)	4 vehicles (2-Retrofits)
2002-2006	3 vehicles (1 retrofit)	2 vehicles
2007-2009	2 vehicles	3 vehicles
2010+	1 vehicle	None

Chassis Dyno Test Vehicles/ Engine Specification

Engine Manufacturer	Caterpillar	Detroit Diesel	Detroit Diesel	Caterpillar	Detroit	Caterpillar	Cummins, Inc.	-Detroit Diesel	Cummins, Inc.	Navistar
Engine Model	3176	DDC Series 60	S60	C-15	DDC Series 60	C-15	ISM 370	MBE4000	ISX 485	*MAXXFORC E*13
Model Year	1994	1998	1999	2000	2000	2005	2006	2007	2008	2009
Test Weight	50000	61250	62154	58744	68460	58600	57300	61250	60260	61200
Chassis Model	1994 Freightliner	1998 Sterling	1999 Freightliner	2001 Freightliner	2001 Freightliner	2006 Peterbilt	2006 International 9200i	2008 Freightliner	2008 Peterbilt	2011 Transtar
Engine Family Name	RCP629E ZDARA	WDDXH12.7E GD	XPOXH 12.7 EGL	XH0893ERK	YDDXH12.7 EGL	5CPXH0928E BK	6CEXH0661 MAT	7DDXH12.8 DJA	8CEXH091 2XAL	Maxforce
Engine Type		In-line 6 cylinder	In-line 6 cylinder	In-line 6 cylinder, 4 stroke	In-line 6 cylinder	In-line 6 cylinder	In-line 6 cylinder, 4 stroke	In-line 6 cylinder, 4 stroke	In-line 6 cylinder	In-line 6 cylinder
Injection Type	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
EGR	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Displacement (liter)	10.3	12.7	12.7	14.6	12.7	15.2	10.8	12.8		12.4
Power Rating (hp)	325 hp @ 1800	470 (peak)	470 hp @ 2100	475 hp @ 2100	470 hp @ 2100	475 hp @ 1800	385 @ 1800 rpm	420 hp @ 1750 rpm	485 (peak) 1650 (continuous)	430 hp(peak)
Fuel Type	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Induction		Turbocharged		Turbocharger with after cooler	Turbocharged		Turbocharger with charge air cooler	Turbocharger with after cooler	Turbocharged	Direct Injection Turbocharged
After treatment		Johnson Matthey SCRT			Cleaire Long View			OEM DPF	OEM DPF	OEM DPF

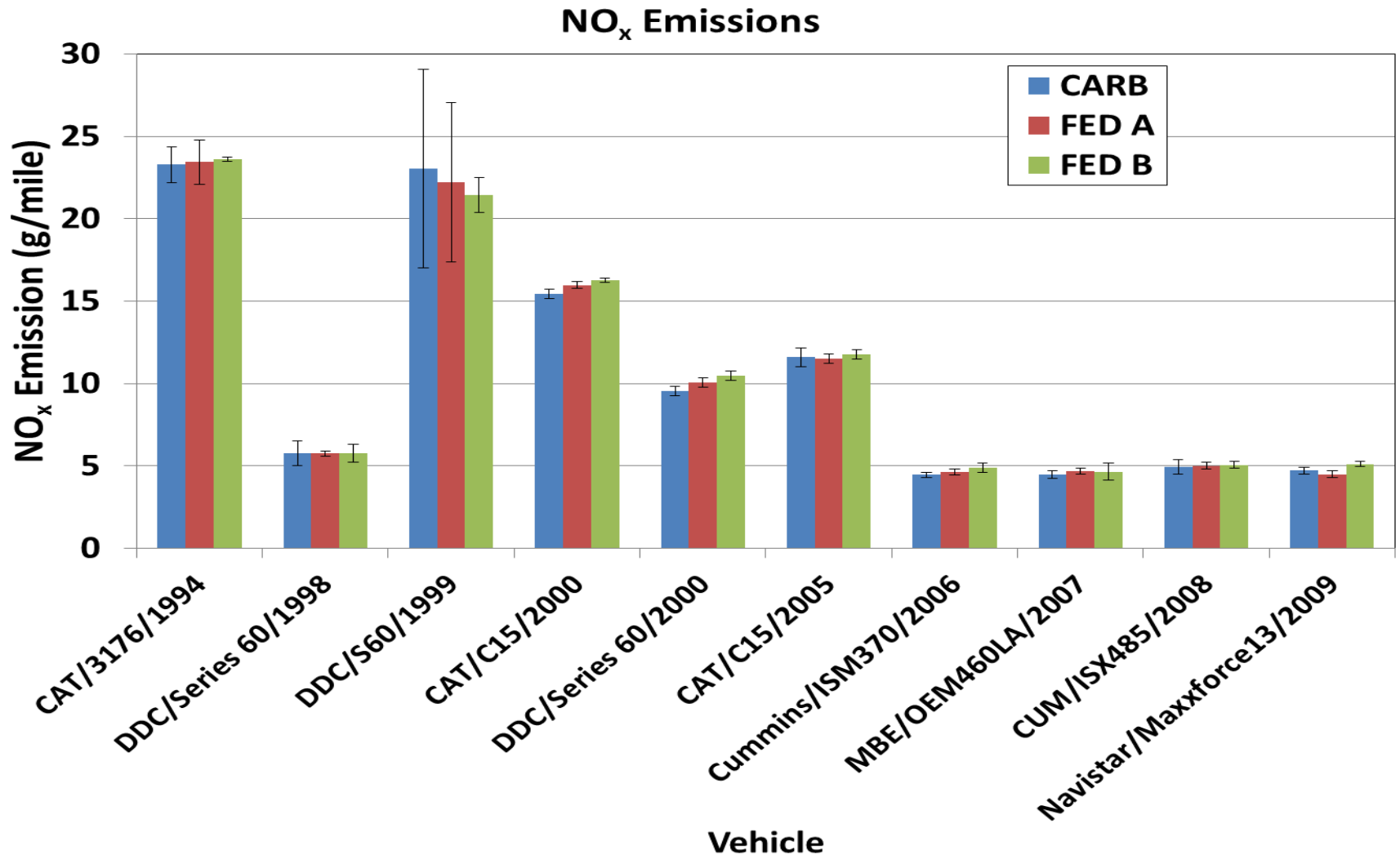
Engine Dyno Tested Engines/Specification

Engine Manufacturer	Detroit Diesel Corp.
Engine Model	MBE4000
Model Year	2007
Engine Family Name	7DDXH12.8DJA
Engine Type	In-line 6 cylinder, 4 stroke
Displacement (liter)	12.8
Power Rating (hp)	Varies, 350-450 hp @ 1900 rpm
Fuel Type	Diesel
Injection Type	Direct
Induction	Turbocharger with after-cooler
EGR	Yes
After-Treatment	DOC/DPF

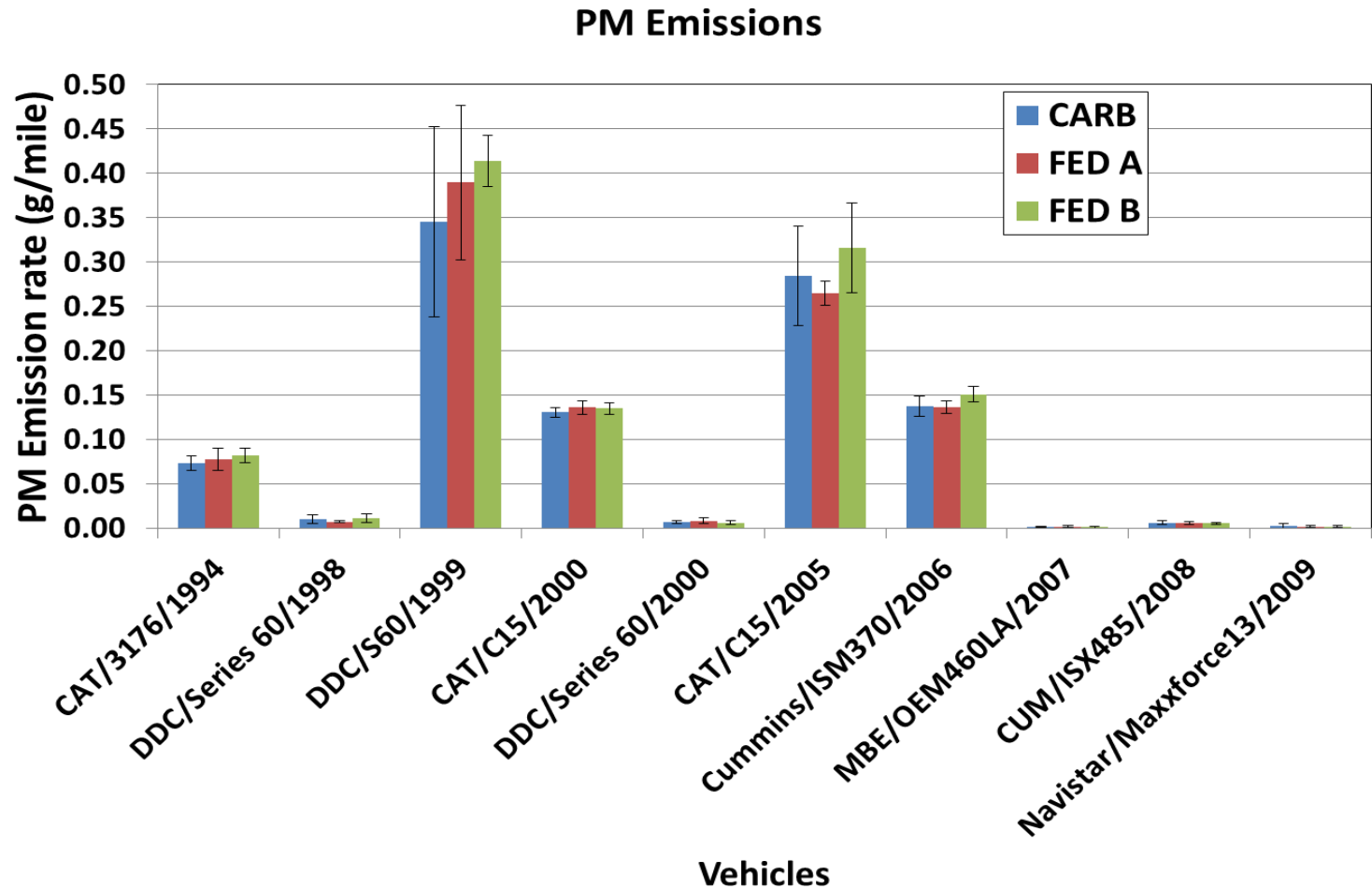
Engine Manufacturer	Cummins, Inc.
Engine Model	ISM 370
Model Year	2006
Engine Family Name	6CEXH0661MAT
Engine Type	In-line 6 cylinder, 4 stroke
Displacement (liter)	10.8
Power Rating (hp)	385 @ 1800 rpm
Fuel Type	Diesel
Injection Type	Direct
Induction	Turbocharger with charge-air cooler
EGR	Yes
After-Treatment	None

Engine Manufacturer	Detroit Diesel Corp.
Engine Model	Series 60
Model Year	1991
Engine Family Name	MDD11.1FZA2
Engine Type	In-line 6 cylinder, 4 stroke
Displacement (liter)	11.1
Power Rating (hp)	360 @ 1800 rpm
Fuel Type	Diesel
Injection Type	Direct
Induction	Turbocharger with after-cooler
EGR	No
After-Treatment	None

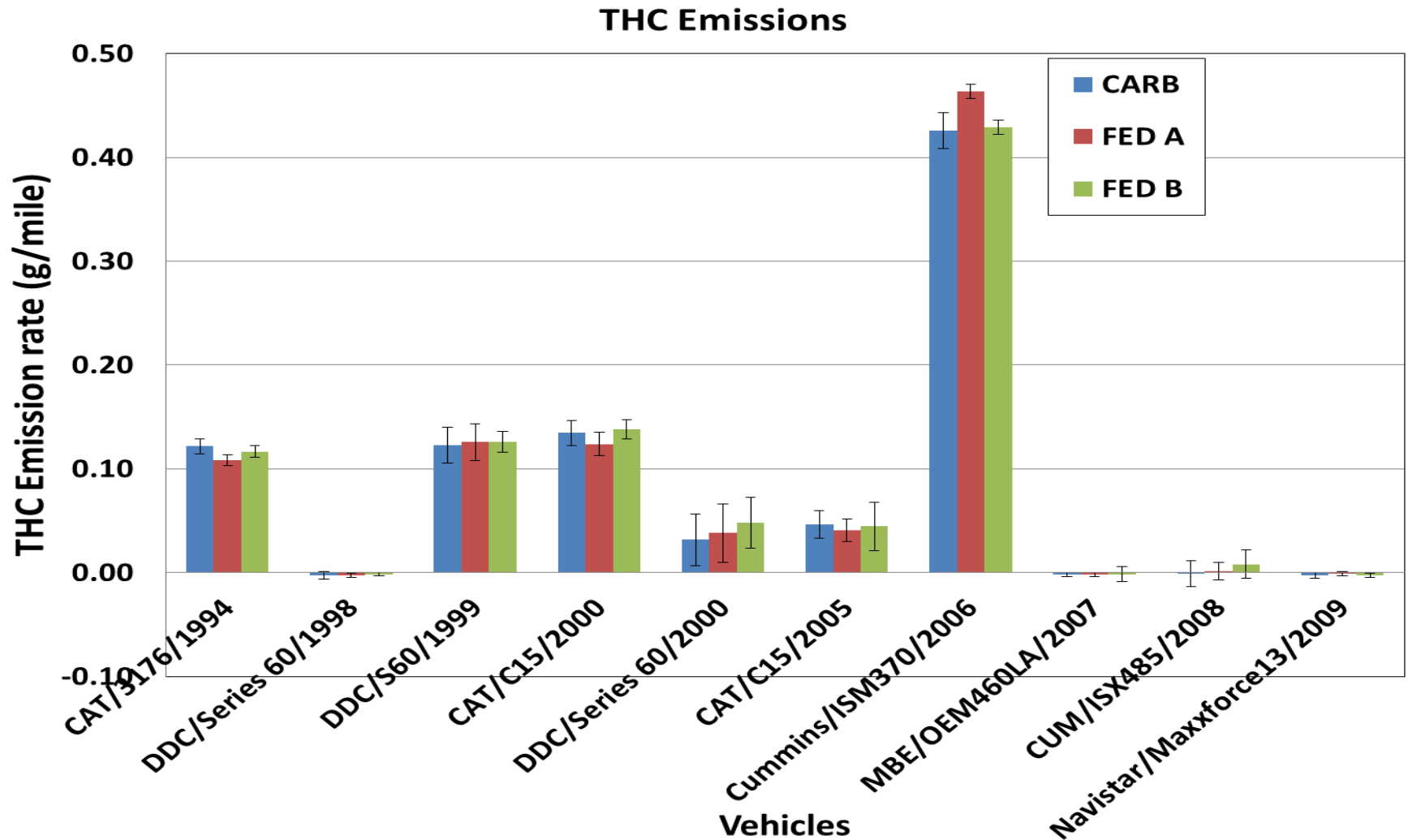
Chassis Dyno Testing NO_x Results



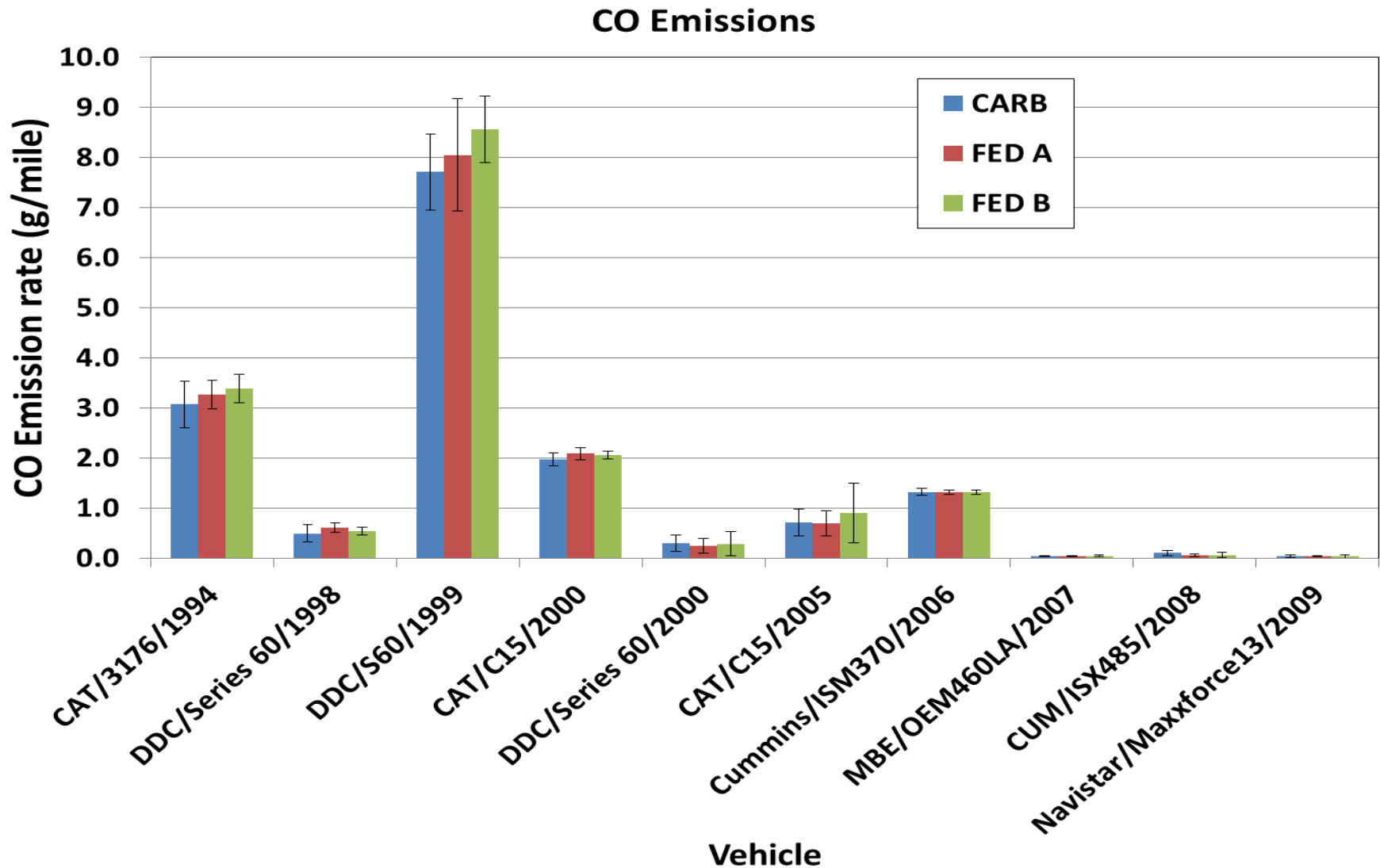
Chassis Dyno Testing PM Results



Chassis Dyno Testing THC Results

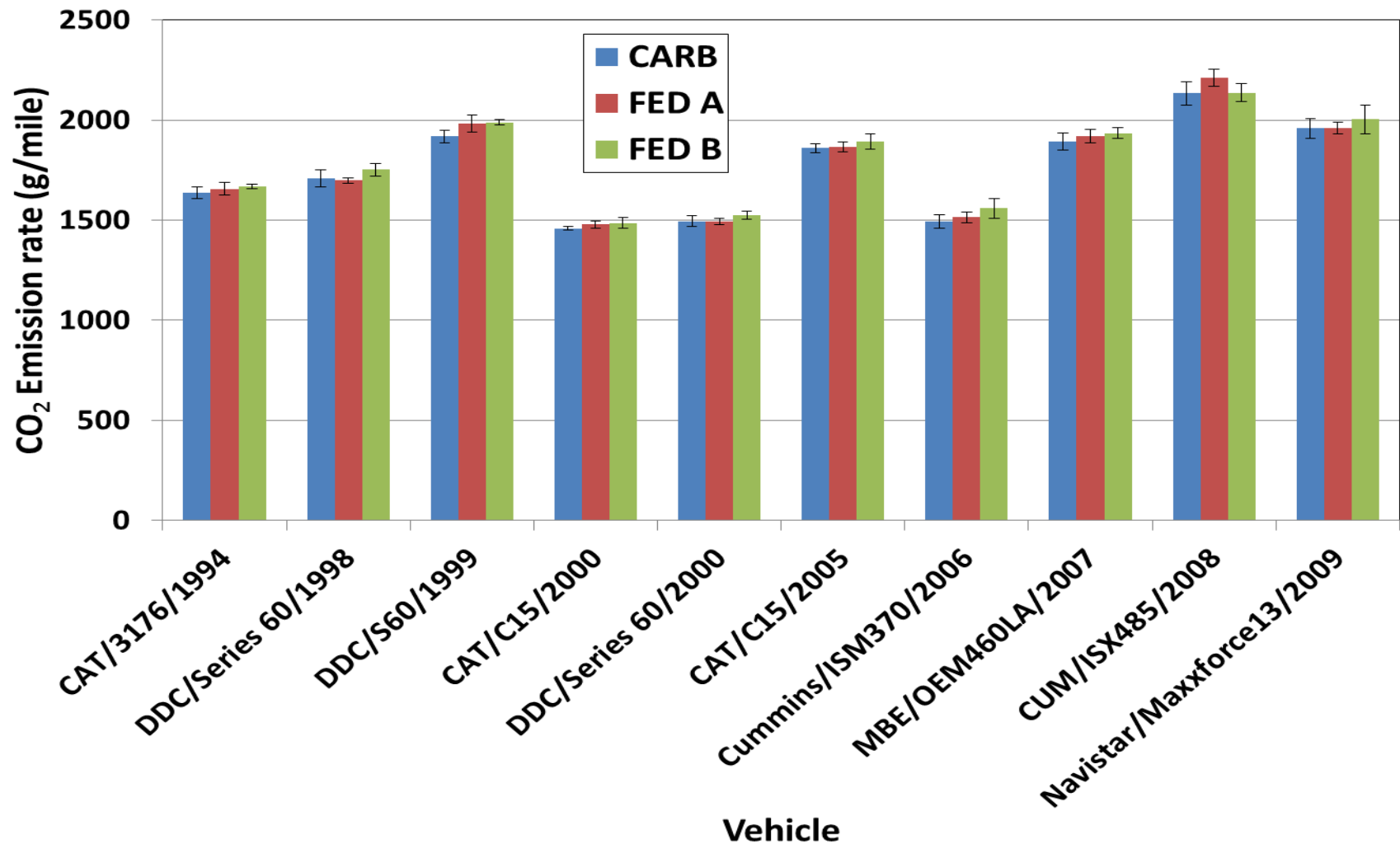


Chassis Dyno Testing CO Results

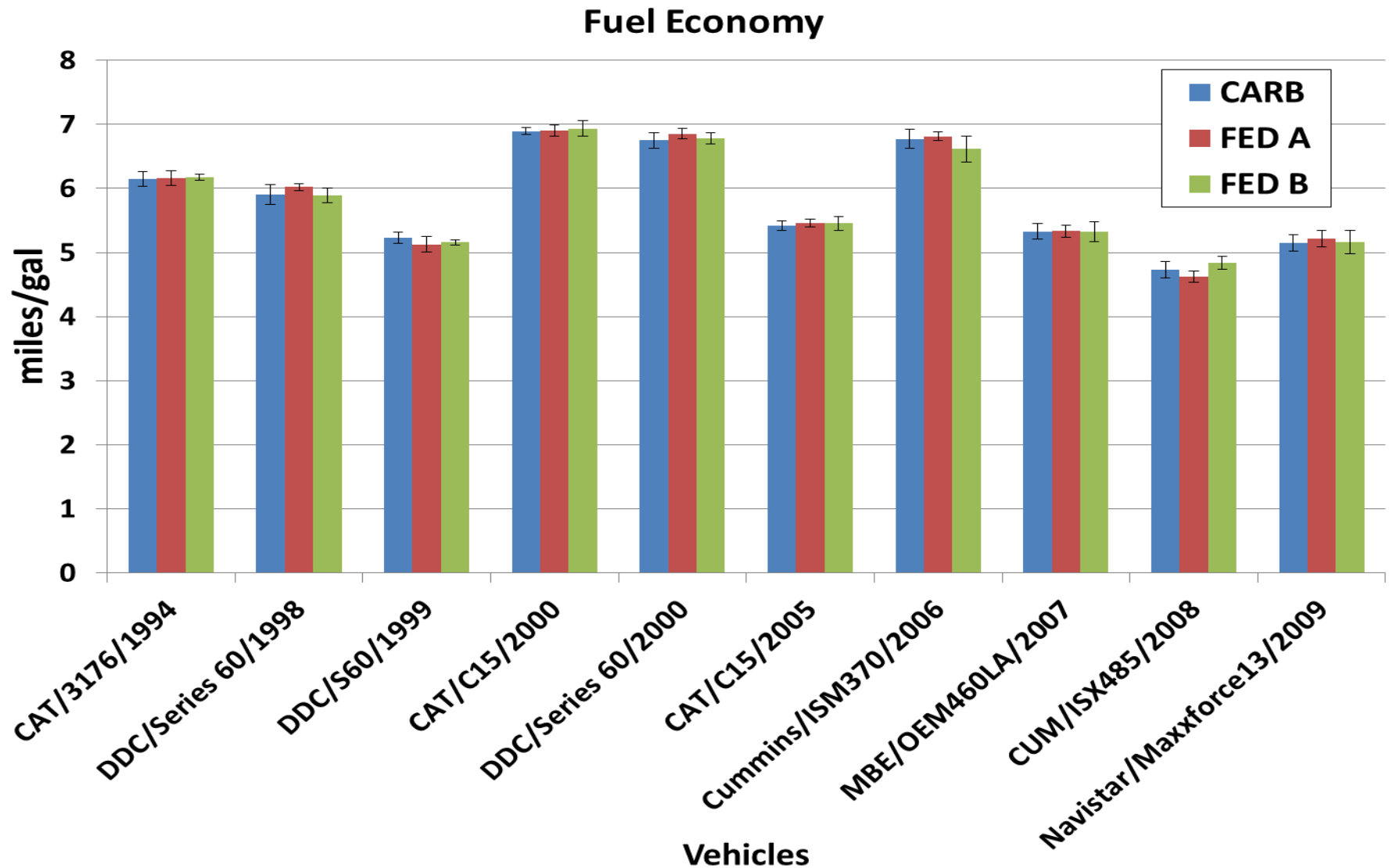


Chassis Dyno Testing CO₂ Results

CO₂ Emissions



Chassis Dyno Testing MPG Results



Chassis Dyno Emission Results

Percentage Difference and P-Value

		THC		CO		NO _x		PM		CO ₂		MPG	
CARB vs.		% diff	P value	% diff	P value	% diff	P value	% diff	P value	% diff	P value	% diff	P value
CAT/3176/1994													
Cruise	Federal A	-11.14%	0.001	6.57%	0.357	0.71%	0.792	5.95%	0.418	1.19%	0.234	0.24%	0.805
	Federal B	-4.11%	0.292	10.35%	0.294	1.44%	0.619	11.75%	0.141	1.90%	0.108	0.46%	0.681
DDC/Series 60/1998													
Cruise	Federal A	9.35%	0.879	22.72%	0.158	-0.28%	0.959	-31.27%	0.121	-0.56%	0.606	1.94%	0.089
	Federal B	-38.78%	0.461	9.49%	0.486	0.29%	0.956	9.66%	0.639	2.58%	0.018	-0.19%	0.854
DDC/S60/1999													
Cruise	Federal A	2.66%	0.644	4.38%	0.358	-3.63%	0.712	12.74%	0.283	3.39%	0.000	-1.87%	0.020
	Federal B	2.79%	0.592	11.13%	0.009	-7.10%	0.431	19.96%	0.074	3.69%	0.000	-1.29%	0.038
CAT/C15/2000													
Cruise	Federal A	-8.11%	0.031	6.35%	0.022	3.33%	0.000	4.32%	0.040	1.28%	0.002	0.16%	0.681
	Federal B	2.33%	0.454	4.54%	0.089	5.26%	0.000	3.29%	0.122	1.86%	0.001	0.57%	0.262
DDC/Series 60/2000													
Cruise	Federal A	21.05%	0.550	-17.34%	0.460	5.40%	0.000	19.86%	0.215	-0.07%	0.920	1.50%	0.039
	Federal B	51.02%	0.139	-1.36%	0.961	9.41%	0.000	-13.28%	0.336	1.92%	0.012	0.47%	0.503
CAT/C15/2005													
Cruise	Federal A	-11.68%	0.351	-2.76%	0.855	-0.98%	0.577	-7.00%	0.307	0.31%	0.567	0.75%	0.196
	Federal B	-4.03%	0.796	26.66%	0.264	1.41%	0.475	10.84%	0.180	1.69%	0.016	0.72%	0.268
Cummins/ISM370/2006													
Cruise	Federal A	8.84%	0.001	-0.40%	0.822	4.15%	0.006	-0.97%	0.749	1.45%	0.086	0.60%	0.610
	Federal B	0.65%	0.696	-0.19%	0.919	9.92%	0.000	9.45%	0.006	4.43%	0.000	-2.35%	0.054
MBE/OEM460LA/2007													
Cruise	Federal A	16.91%	0.766	1.30%	0.920	4.83%	0.025	13.60%	0.581	1.30%	0.175	0.12%	0.899
	Federal B	-11.72%	0.833	23.58%	0.163	4.03%	0.052	-16.83%	0.543	2.19%	0.022	-0.03%	0.830
CUM/ISX485/2008													
Cruise	Federal A	-260.62%	0.628	-42.05%	0.011	1.54%	0.605	0.03%	0.998	3.62%	0.001	-2.14%	0.038
	Federal B	-1079.75%	0.149	-37.24%	0.073	2.75%	0.446	-9.33%	0.464	0.13%	0.901	2.25%	0.042
Navistar/Maxxforce 13/2009													
Cruise	Federal A	-59.29%	0.132	-13.86%	0.532	-4.51%	0.021	-26.47%	0.615	0.07%	0.938	1.33%	0.162
	Federal B	-3.41%	0.925	-30.53%	0.223	8.67%	0.000	-7.22%	0.893	2.26%	0.072	0.21%	0.860

Engine Dyno Emission Results

Percentage Difference Difference and P-Value

		THC		CO		NO _x		PM		CO ₂		BSFC	
CARB vs.		% diff	P value	% diff	P value	% diff	P value	% diff	P value	% diff	P value	% diff	P value
2007 MBE 4000													
FTP	Federal B	27%	0.135	51%	0.000	7.3%	0.000	53%	0.752	1.4%	0.000	-0.9%	0.000
Cruise	Federal B	-14%	0.270	31%	0.024	4.7%	0.000	109%	0.297	2.0%	0.000	-0.4%	0.255
2006 Cummins ISM													
FTP	Federal A	-1%	0.633	17%	0.000	6.7%	0.000	5%	0.000	1.3%	0.000	-0.1%	0.667
	Federal B	12%	0.000	23%	0.000	7.9%	0.000	8%	0.000	1.3%	0.000	-1.0%	0.002
Cruise	Federal A	-13%	0.000	5%	0.041	9.5%	0.001	0%	0.831	0.9%	0.004	-0.5%	0.080
	Federal B	0%	0.904	9%	0.002	8.1%	0.020	3%	0.278	2.0%	0.000	-0.4%	0.348
1991 DDC													
FTP	Federal A	14%	0.000	9%	0.000	7.5%	0.000	2%	0.425	1.7%	0.003	0.3%	0.524
	Federal B	30%	0.000	12%	0.000	9.3%	0.000	3%	0.341	1.2%	0.013	-1.2%	0.014
Cruise	Federal A	1%	0.756	5%	0.009	5.3%	0.000	7%	0.011	1.4%	0.000	-0.1%	0.589
	Federal B	14%	0.000	3%	0.070	7.3%	0.000	2%	0.330	1.7%	0.000	-0.7%	0.000

Dyno Statistical Analysis Results

Weighted Difference and Confidence Interval

50-mph Cruise Cycle

		THC		CO		NOx		PM		CO ₂	
		Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI
All trucks & Engines	Federal A	-2.5%	9.0%	2.3%	8.0%	3.5%	2.1%	1.2%	8.9%	1.2%	0.6%
	Federal B	2.2%	10.7%	5.3%	9.9%	5.7%	2.2%	4.9%	17.5%	2.0%	0.5%
Trucks & Engines w EGR	Federal A	-1.2%	10.9%	-1.3%	12.5%	2.3%	2.9%	-1.5%	13.8%	1.1%	0.8%
	Federal B	-0.8%	9.7%	4.6%	17.1%	5.5%	2.0%	5.1%	32.2%	2.0%	0.8%
Trucks & Engines w/o EGR	Federal A	-4.1%	13.6%	5.5%	9.3%	4.1%	3.4%	4.3%	11.5%	1.2%	0.8%
	Federal B	5.4%	17.1%	5.8%	8.8%	5.8%	4.2%	4.8%	9.0%	2.1%	0.6%
Trucks & Engines w DPF	Federal A	NA	NA	-7.3%	17.4%	2.0%	2.8%	-5.5%	20.6%	0.7%	1.1%
	Federal B	NA	NA	5.2%	19.9%	5.8%	2.5%	-3.6%	39.4%	1.9%	0.7%
Trucks & Engines w/o DPF	Federal A	-2.7%	5.2%	3.6%	4.0%	4.0%	3.1%	2.1%	4.5%	1.3%	0.6%
	Federal B	2.1%	5.1%	5.3%	7.9%	5.7%	3.5%	6.1%	4.5%	2.1%	0.7%

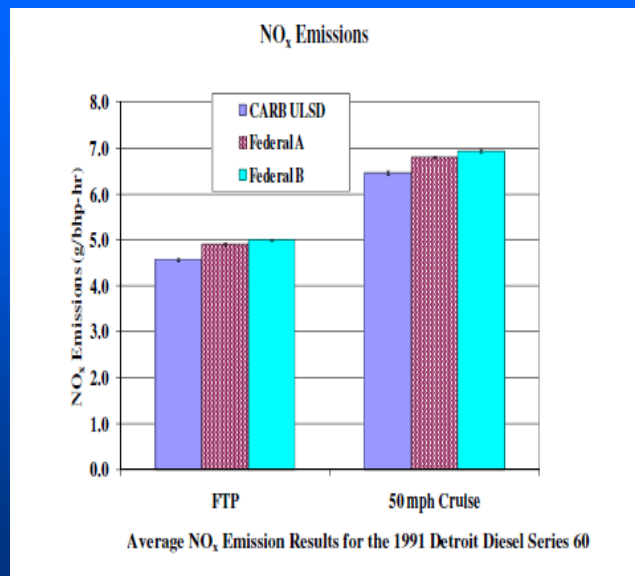
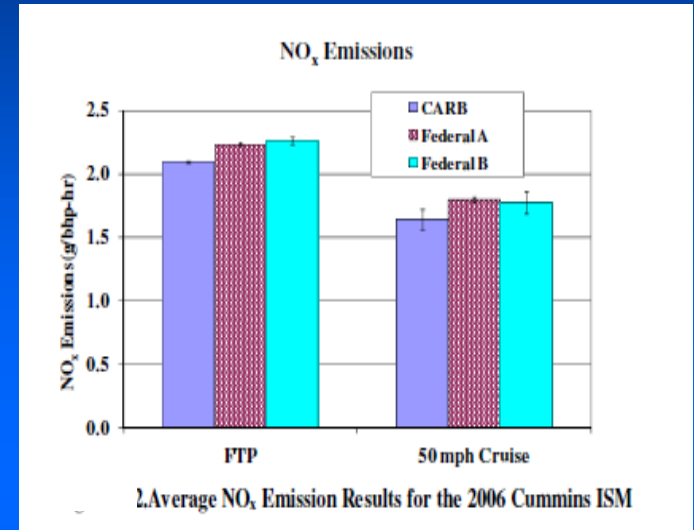
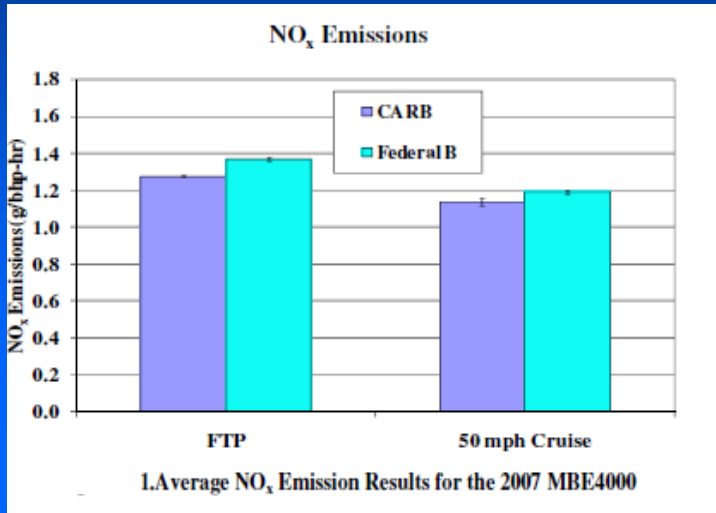
FTP Cycle

		THC		CO		NOx		PM		CO ₂	
		Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI	Wt'd%Δ	95% CI
All Engines	Federal A	4.7%	9.1%	13.9%	4.7%	7.0%	0.6%	4.4%	2.8%	1.4%	0.4%
	Federal B	18.4%	11.7%	21.9%	16.0%	8.3%	0.8%	7.4%	4.5%	1.3%	0.3%
Engines w EGR	Federal A	-0.7%	2.5%	16.8%	1.7%	6.7%	0.6%	4.9%	1.1%	1.3%	0.3%
	Federal B	13.1%	17.6%	25.8%	21.2%	7.5%	0.7%	8.5%	1.1%	1.4%	0.2%
Engine w/o EGR	Federal A	14.4%	4.4%	9.1%	2.9%	7.5%	0.7%	2.1%	4.9%	1.7%	0.9%
	Federal B	29.5%	4.9%	12.2%	3.2%	9.3%	0.6%	2.6%	5.2%	1.2%	0.8%
Engine w DPF	Federal A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Federal B	27.3%	32.9%	51.3%	11.5%	7.3%	0.7%	NA	NA	1.4%	0.3%
Engines w/o DPF	Federal A	4.7%	9.1%	13.9%	4.7%	7.0%	0.6%	4.4%	2.8%	1.4%	0.4%
	Federal B	18.0%	10.7%	19.4%	6.4%	8.8%	1.0%	7.4%	4.5%	1.3%	0.4%

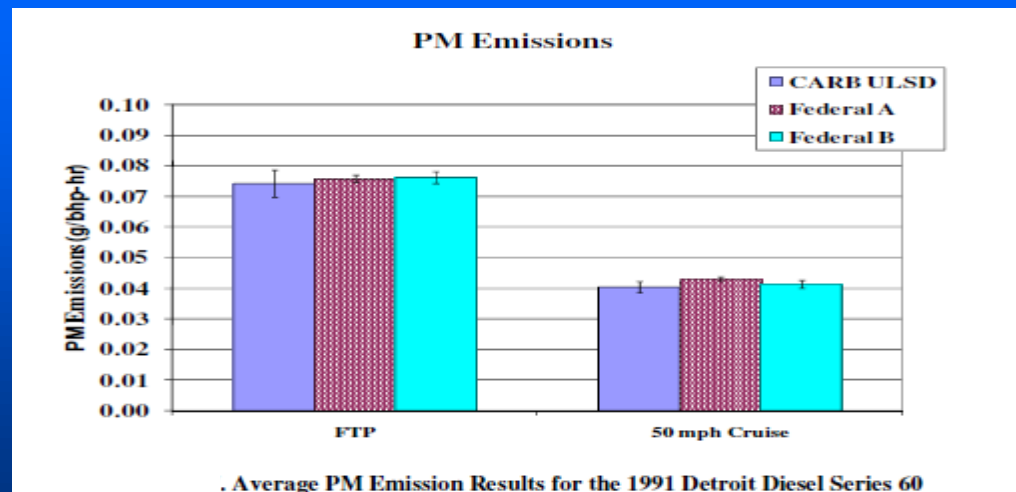
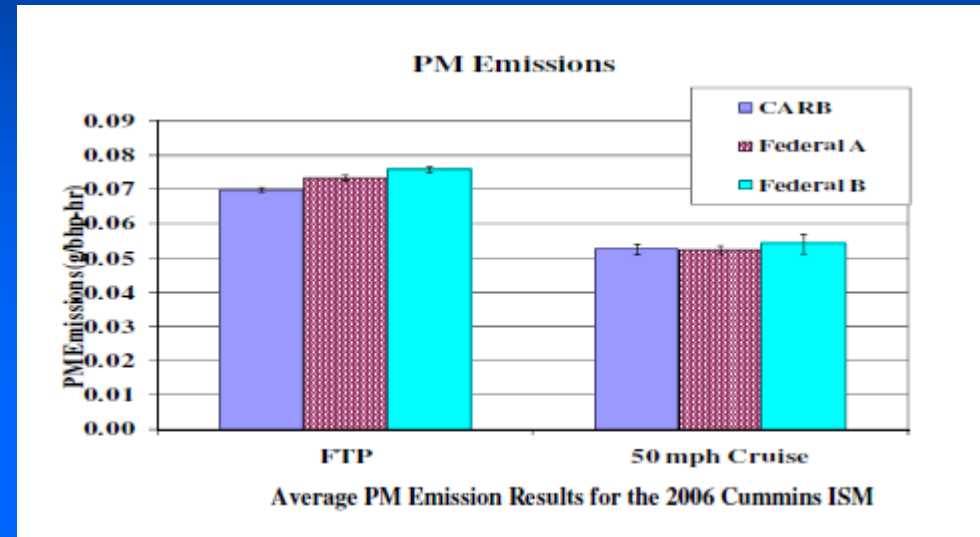
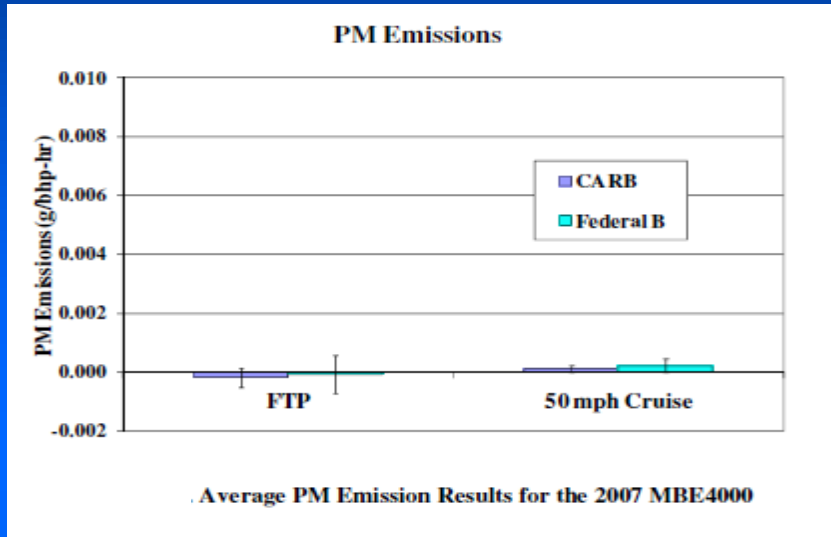
Additional Discussion

- Comments on chassis dynamometer results or statistical analysis
- Comments on draft final report
- Engine dynamometer data are included in the presentation in case additional discussion is needed

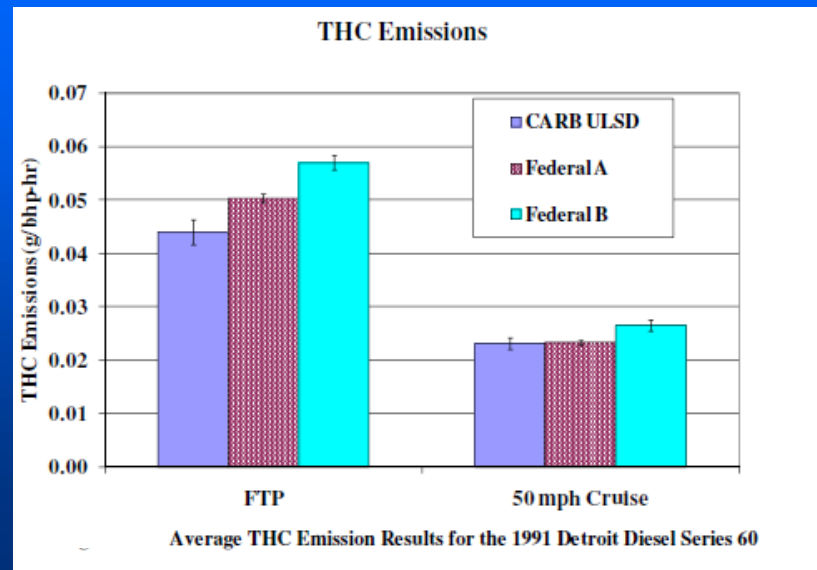
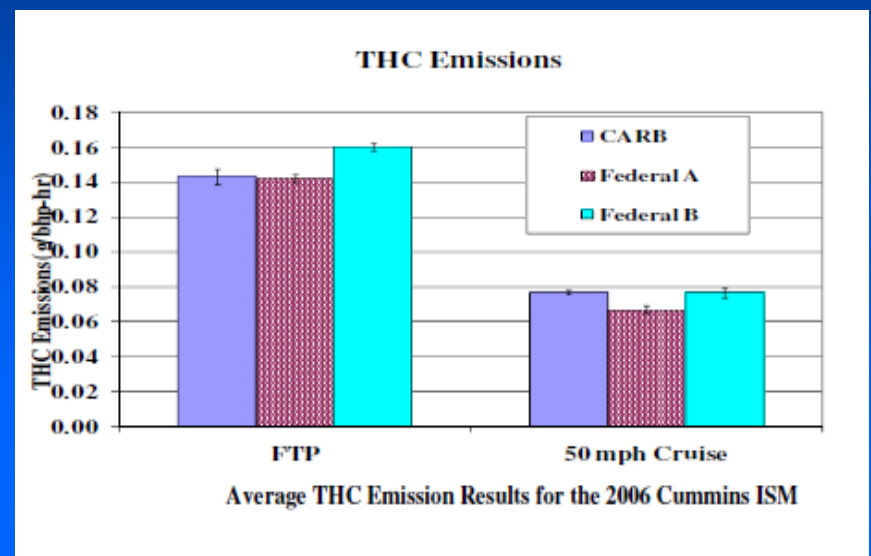
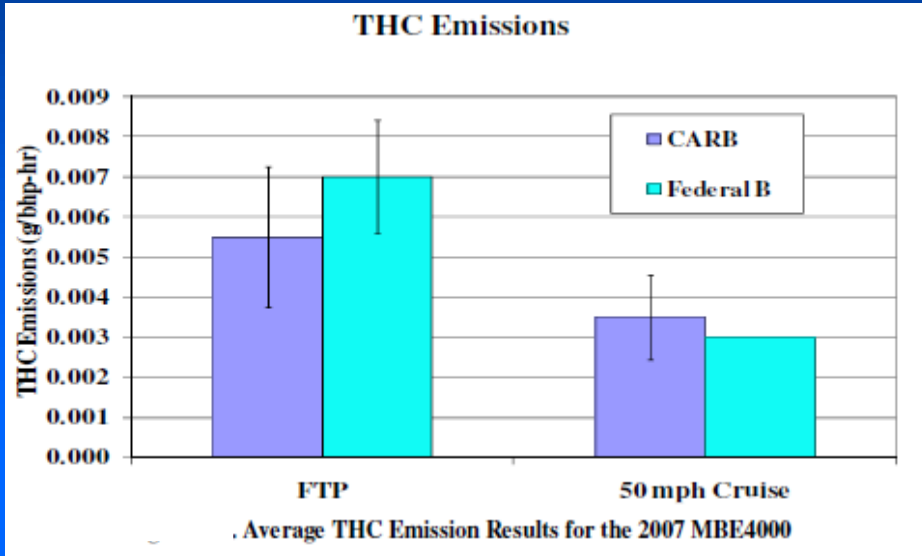
Engine Dyno Testing NO_x Results



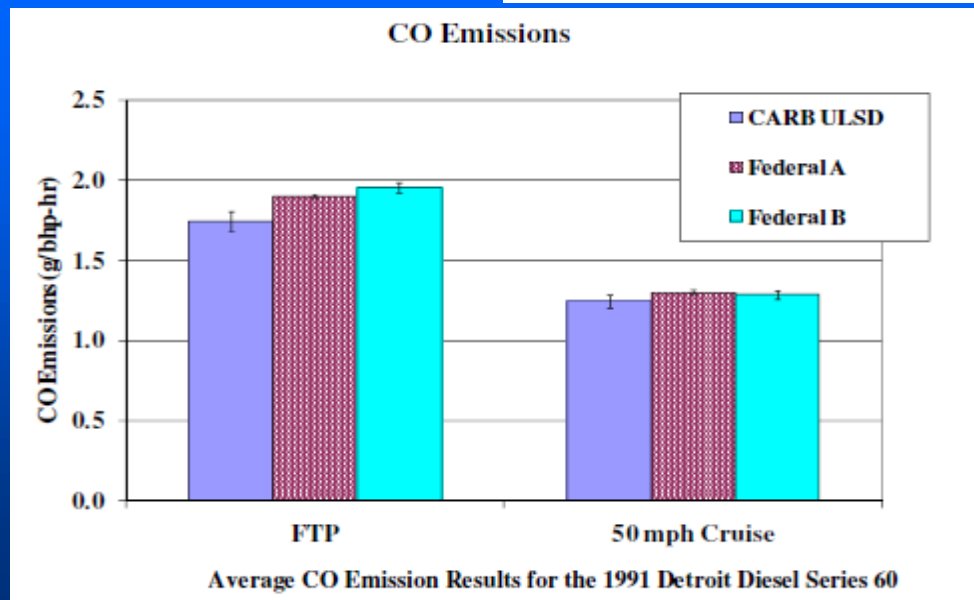
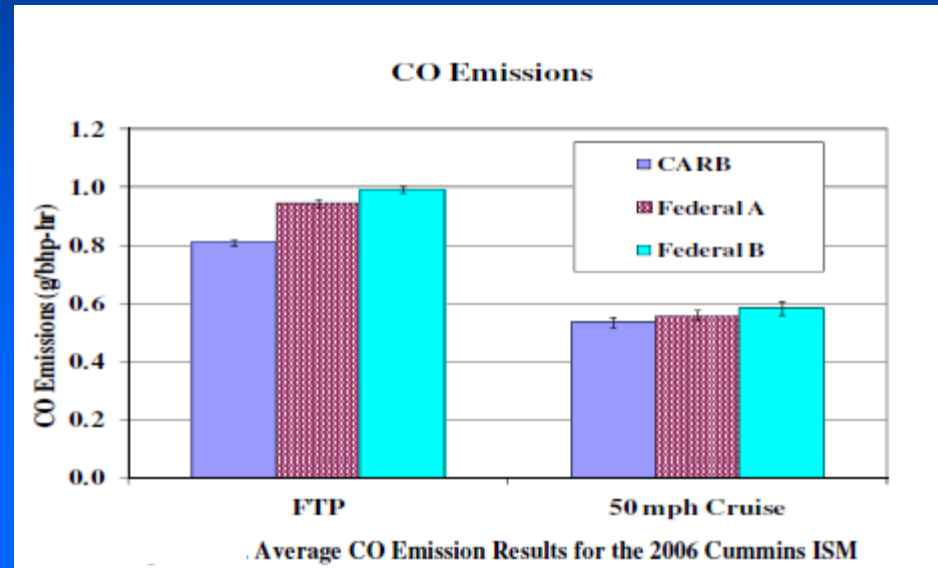
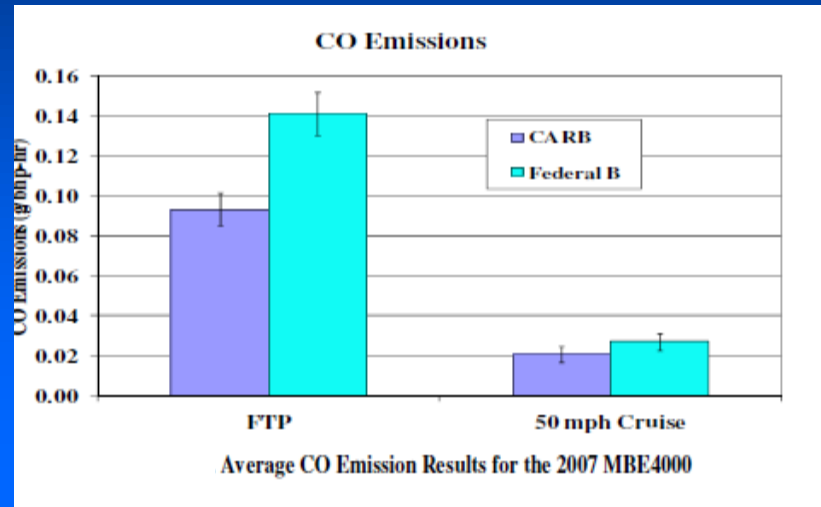
Engine Dyno Testing PM Results



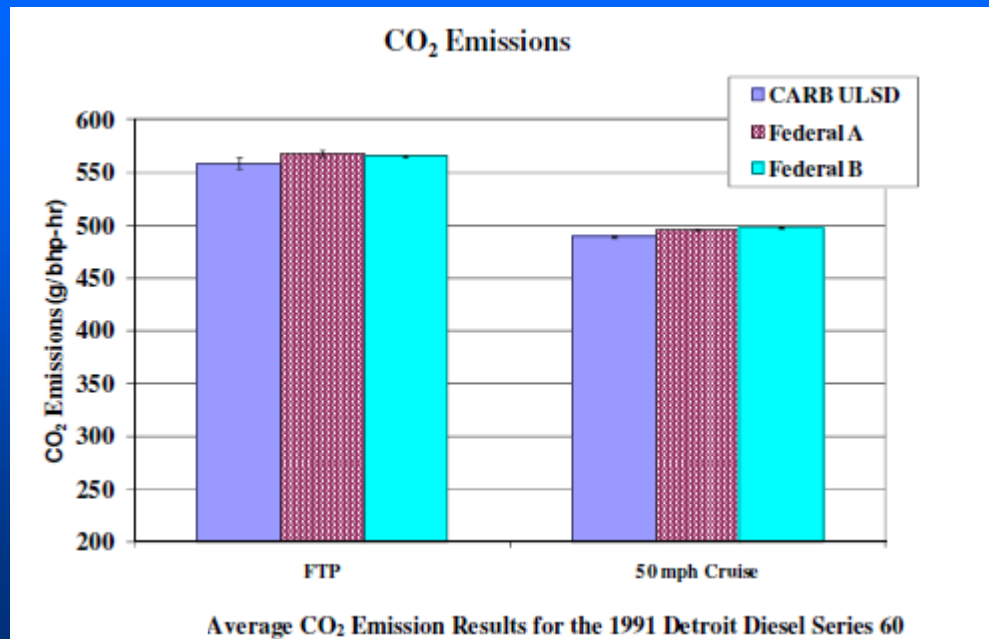
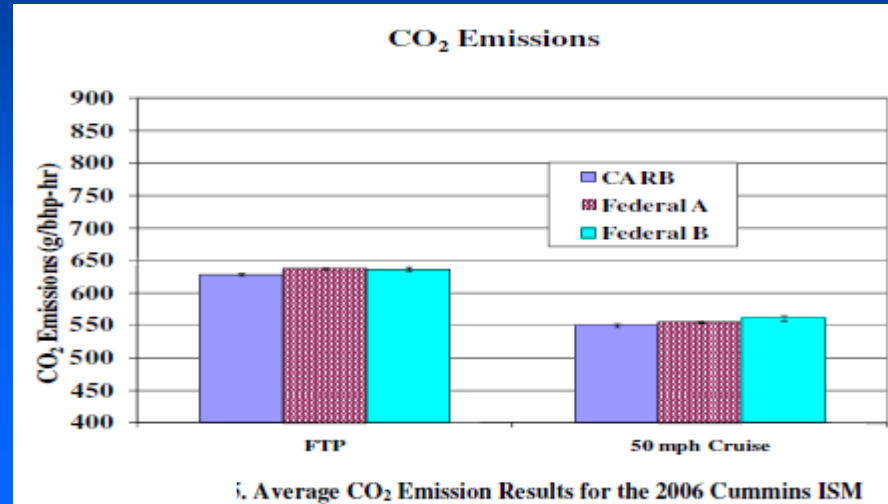
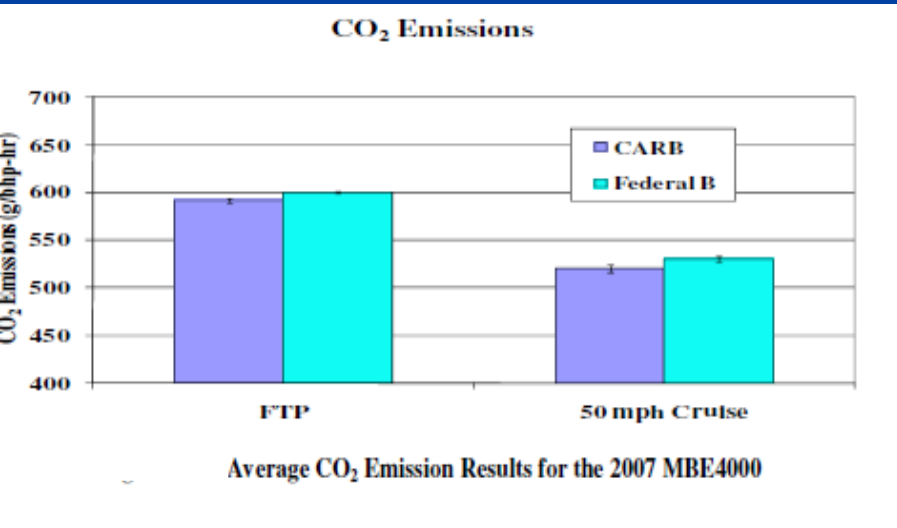
Engine Dyno Testing THC Results



Engine Dyno Testing CO Results



Engine Dyno Testing CO₂ Results



Engine Dyno Testing BSFC Results

